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by

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Abstract: Research on the impact of innovation on regional economic performance in Europe has fundamentally followed three approaches: a) the analysis of the link between investment in R&D, patents, and economic growth; b) the study of the existence and efficiency of regional innovation systems; and c) the examination of the geographical diffusion of regional knowledge spillovers. These complementary approaches have, however, rarely been combined. Important operational and methodological barriers have thwarted any potential cross-fertilization. In this paper, we try to fill this gap in the literature by combining in one model R&D, spillovers, and innovation systems approaches. A multiple regression analysis is conducted for all regions of the EU-25, including measures of R&D investment, proxies for regional innovation systems, and knowledge and socio-economic spillovers. This approach allows us to discriminate between the influence of internal factors and external knowledge and institutional flows on regional economic growth. The empirical results highlight how the complex interaction between local and external research, on the one hand, with local and external socio-economic and institutional conditions, on the other, shapes the innovation capacity of every region. They also indicate the importance of proximity for the transmission of economically productive knowledge, as spillovers are affected by strong distance decay effects.

JEL Classification: R11, R12, R58

Keywords: Economic growth, innovation, R&D, knowledge, spillovers, innovation systems, regions, European Union

I+D, 'spillovers', sistemas de innovación y la génesis del crecimiento regional en Europa

La investigación sobre el impacto de la innovación sobre el desempeño económico en Europa ha seguido fundamentalmente tres enfoques: a) el análisis del vínculo entre la inversión en I+D, patentes y crecimiento económico; b) el estudio de la existencia y eficacia de sistemas de innovación regionales y c) el examen de la difusión geográfica del conocimiento (spillovers). A pesar de su complementariedad, estos enfoques apenas se han combinado. La presencia de barreras metodológicas y operacionales ha minado cualquier posibilidad de interacción. En este artículo nuestra intención es cubrir este hueco en la literatura, combinando en un modelo los enfoques basados I+D, spillovers y sistemas de innovación. Esto se realiza mediante un análisis de regresión múltiple que incluye variables de inversión en I+D, componentes de los sistemas de innovación regional y spillovers de conocimiento y de carácter socioeconómico. Este enfoque nos permite discriminar entre la influencia de los factores internos y los flujos externos de conocimiento e institucionales sobre el crecimiento económico. Los resultados empíricos subrayan cómo la interacción entre la investigación local y la realizada en otros espacios, por un lado, con las condiciones socioeconómicas e institucionales tanto en el ámbito local como en otras áreas, por otro, influye en la capacidad innovativa de cada región. Los resultados también ponen de manifiesto la importancia de la cercanía geográfica en la transmisión del conocimiento productivo, ya que la eficacia de los spillovers se ve fuertemente afectada por la distancia.

Clasificación JEL: R11, R12, R58

Palabras clave: Crecimiento económico, innovación, I+D, conocimiento, spillovers, sistemas de innovación, regiones, Unión Europea

1. Introduction

The capacity to innovate and to assimilate innovation have regularly been considered as two of the key factors behind the economic dynamism of any territory (Feldman and Florida, 1994; Audretsch and Feldman, 1996; Cantwell and Iammarino, 1998; Furman, Porter, and Stern, 2002). Yet, despite this agreement on the essentials, different researchers have tried to untangle the link between research, innovation, and economic growth in very different ways. Three different approaches to this relationship predominate. The first is the so-called 'linear model' (Bush, 1945; Maclaurin, 1953), whereby basic research leads to applied research and to inventions, that are then transformed into innovations, which, in turn, lead to greater growth. Empirically, this type of analysis focuses fundamentally on the link between R&D and patents, in the first instance, followed by that between patents and growth. Such analyses are fundamentally conducted by 'mainstream economists' and, despite criticisms (e.g. Rosenberg, 1994), the approach remains popular with academics and policy makers. A second group can be classified under the denominations of 'systems of innovation' (Lundvall, 1992) or 'learning region' (Morgan, 1997) approaches. These approaches, associated with evolutionary economics (Dosi et al, 1988; Freeman, 1994), concentrate on the study of territorially-embedded institutional networks that favour or deter the generation of innovation. The capacity of these networks to act as catalysts for innovation depends, in turn, on the combination of social and structural conditions in every territory, the so-called 'social filter' (Rodríguez-Pose, 1999). These approaches tend to be fundamentally qualitative and mainly conducted by geographers, evolutionary economists, and a number of economic sociologists. Finally, there is a large group of scholars who has mainly concentrated on the diffusion and assimilation of innovation (Jaffe, 1986; Audretsch and Feldman, 1996; Cantwell and Iammarino, 2003; Sonn and Storper, 2005). This knowledge spillovers approach has been generally adopted by economists and geographers, using both quantitative and qualitative methods.

Although such a variety of approaches contributes to improve our understanding of the process of innovation and of the linkages between innovation and economic development, there has been little cross-fertilisation between these different, but nevertheless complementary strands of literature. Major operational and methodological barriers have hitherto kept any potential interaction to a bare minimum. The main reasons for this lack of interaction are related to the different disciplinary backgrounds of the researchers working on innovation, to the different methods used in the various approaches, and to the difficulties in operationalising some of the concepts employed by the diverse scholarly strands.

This paper represents an attempt to try to bridge this gap in the literature by combining in one model linear, innovation systems, and spillover approaches. The aim is to show how factors which have been at the centre of these research strands (i.e. innovative effort, socio-institutional contextual factors, and localised knowledge spillovers) interact and account for a significant part of the growth trends of the regions of the enlarged EU after 1995. An additional objective is to shed new light on the role of geographical distance in the process of innovation, by focusing on the "continuing tension between two opposing forces" (Storper and Venables 2004, p.367): the increasingly homogeneous availability of standard 'codified' knowledge, on the one hand, and the spatial boundedness of 'tacit' knowledge and contextual factors, on the other. Such tension is an important determinant of the present economic geography of European regions, which is further accentuated by the underlying socio-economic differences.

In order to achieve this aim, we ground our approach on a series of fundamental theoretical mechanisms which make knowledge and its transmission an important explanation for regional diversity in economic growth. First, that, as highlighted by the linear model of innovation, local innovative activities are crucial for the 'production' of new knowledge and the economic exploitation of existing knowledge, given the presence of a minimum threshold of local innovation capabilities (as put forward by evolutionary economics and neo-Schumpeterian strands). Such activities are not geographically evenly distributed and thus become a localised source of competitive advantage for some areas rather than others. Second, that information is not automatically equivalent to economically-useful knowledge (Sonn and Storper, 2005). A successful process of innovation depends on "localised structural and institutional factors that shape the innovative capacity of specific geographical contexts" (Iammarino, 2005, p.499), as indicated by the systems of innovation (Lundvall, 2001), regional systems of innovation (Cooke et al., 1997), and learning regions (Morgan, 2004; Gregersen and Johnson, 1996) approaches. And third, that technological improvements in 'communication infrastructures' have not affected all kinds of information in the same way. While 'codified information' can be transmitted over increasingly large distances, 'tacit' knowledge tends to be geographically bound and a key factor behind the concentration of innovation (Audretsch and Feldman, 2004; Cantwell and Iammarino, 2003; Sonn and Storper, 2005; Charlot and Duranton, 2006; Iammarino and McCann, 2006).

The paper is organised into four further sections. First, we introduce the theoretical framework for the analysis. The second section presents the empirical model and provides its theoretical justification. In the third section the empirical results are discussed. The final section concludes with some economic policy implications.

2. R&D, innovation systems and knowledge spillovers

From a pure neoclassical perspective, factors such as the percentage of investment in research and development (R&D) or where the actual research is conducted matter little. The traditional neoclassical view of knowledge as a public good (non rivalrous and non excludable), available everywhere and to everybody simultaneously implies that innovation flows frictionless from producers to a full set of intended and unintended beneficiaries (as 'manna from heaven'), contributing to generate a long-term process of convergence across countries and regions (Solow, 1957; Borts and Stein, 1964). However, this view of innovation as a factor that could be overlooked in the genesis of economic development is now firmly on the retreat. It is not just that innovation is considered as one of the key sources of progress (Fagerberg 1994), but also that technology and innovation have become regarded as essential instruments in any development policy (Trajtenberg, 1990). Differences in innovation capacity and potential become thus, from an 'endogenous growth' perspective (e.g. Grossman and Helpman, 1991), one of the basic explanations for persistent differences in wealth and economic performance. By bringing innovation to the fore, it is often assumed that greater investment in basic R&D will lead to greater applied research and to an increase in the number of inventions, that, when introduced in the production chain, become growth-enhancing innovations. This linear perception of the innovation process places localised R&D investment at the heart of technological progress and, eventually, economic growth. In essence, the implications of this approach are that the higher the investment in R&D, the higher the innovative capacity, and the higher the economic growth. Despite being much derided (e.g. Fagerberg, 1988; Verspagen, 1991; Rosenberg, 1994; Morgan, 1997), the linear model remains popular with academics and policy makers because of its simplicity and powerful explanatory capacity: nations and regions that invest more in R&D, generally tend to innovate more, and often grow faster. But by focusing on local R&D, the linear model completely overlooks key factors about how innovation is actually generated. These factors are related to the context in which innovation takes place and to the potential for territories to assimilate innovation being produced elsewhere.

It has now become widely accepted that innovation is a territorially-embedded process and cannot be fully understood independently of the social and institutional conditions of every space (Lundvall, 1992; Asheim, 1999). The 'territorially-embedded' factors influencing the process of innovation have thus become the main focus for a number of theoretical perspectives: from innovative milieus (Camagni, 1995) and industrial districts (Becattini, 1987) to learning regions (Morgan, 1997) and systems of innovation (Cooke et al., 1997; Cooke, 1998). These approaches are characterised by powerful insights that help us improve our understanding of how and under which conditions the process of innovation takes place. Some of the most relevant findings related to these approaches are the relevance of proximity, local synergies, and interaction (Camagni, 1995, p.317) and the importance of "inter-organization networks, financial and legal institutions, technical agencies and research infrastructures, education and training systems, governance structures, innovation policies" (Iammarino, 2005, p.499) in shaping innovation. The explanatory capacity of such approaches is, however, somewhat constrained by the problems of operationalising in a relatively homogenous way across space the territorially-embedded networks, social economic structures, and institutions that lie at their heart. By nature, the systemic interactions among (local) actors are intrinsically unique and thus hard to measure and compare across different systems. A potential solution to this problem is the 'evolutionary integrated view of the regional systems of innovation' (Iammarino, 2005). From the perspective of evolutionary economics, a meso-level analysis can be developed by contrasting the macro-level (national systems) with the micro-level (the level of the individual innovative actors). This meso-level constitutes "the essential thing that is changing in a process of evolutionary economic change" (Dopfer et al., 2004, p.269) and accounts for local and regional variety in terms of absorption, diffusion, and generation of new knowledge[1]. The concepts of industrial district, learning region, innovation system, etc. – from an evolutionary economics point of view – can all be referred back to this 'meso' perspective. An integrated micro-meso-macro approach to the socio-institutional determinants of innovative performance is a means for dealing with the heterogeneity and path dependency – in terms of "local structural regularities from past knowledge accumulation and learning" (Iammarino, 2005, p. 503) – of the regional economy which, in its turn, shapes and constrains new growth opportunities. This approach provides a flexible theoretical tool for the identification of a series of "external conditions in which externalised learning and innovation occur" (Cooke et al., 1997, p.485) that can be identified across innovation systems and on which innovation strategies can be based. These factors act as "conditions that render some courses of action easier than others" (Morgan, 2004) or as 'social filters', that is, the unique combination "of innovative and conservative (…) elements that favour or deter the development of successful regional innovation systems" (Rodríguez-Pose, 1999, p. 82) in every space.

Finally territories rely not only on their internal capacity to produce innovation either through direct inputs in the research process or through the creation of innovation prone systems in the local environment, but also on their capacity to attract and assimilate innovation produced elsewhere. At the micro-level, innovative units (R&D departments within firms, universities, research centres, etc.), as well as local institutions and individuals, interact with each other and with their external environment through the networks described above. Such interactions produce the transmission of knowledge in the form of ‘knowledge spillovers’ (Jaffe, 1986; Acs, Audretsch, and Feldman, 1992) that are reaped by local actors. The origin of knowledge spillovers can be local, but they can also be generated outside the borders of the locality or region object of the analysis, as “there is no reason that knowledge should stop spilling over just because of borders, such as a city limit, state line or national boundary” (Audretsch and Feldman, 2004, p.6). As there are internal and external sources of spillovers, important questions arise. The first relate to the balance between internally generated innovation and externally transmitted knowledge and the extent to which a territory can rely on externally-generated knowledge for innovation. The second group of questions concerns the local and external conditions that maximise the diffusion of knowledge. The final group deals with the capacity of knowledge spillovers to travel and the potential for distance decay effects. In order to address these questions we have to resort to the theoretical distinction between codifiable information and tacit knowledge. According to Leamer and Storper (2001, p. 650) codifiable information “is cheap to transfer because its underlying symbol systems can be widely disseminated through information infrastructure”. Hence codifiable information can be disseminated relatively costlessly over large distances and does not suffer from strong distance decay effects. However, all information is not completely codifiable. The presence of some specific features make, in some cases, codification impossible or too expensive. “If the information is not codifiable, merely acquiring the symbol system or having the physical infrastructure is not enough for the successful transmission of a message” (Storper and Venables, 2004, p.

354). In the latter case there is thus a need to disseminate tacit knowledge by an intrinsically ‘spatial’ communication technology, among which face-to-face interaction is key. Face-to-face contacts, as discussed in Storper and Venables (2004) or in Charlot and Duranton (2006), do not only act as a communication technology but also pursue other functions (such as generating greater trust and incentives in relationship, screening and socialising, rush and motivation) which make communication not only possible but also more effective, and ultimately ease the innovation process.

However, and in contrast with codifiable information, the process of transmission of tacit knowledge is costly and suffers from strong distance decay effects. Face-to-face contacts are maximised within relatively small territories, due to a combination of proximity and the presence of common socio-institutional infrastructures and networks. The potential to reap knowledge spillovers will thus be maximised within the region. Some of this knowledge will nevertheless spill over beyond the borders of the region or locality flowing into neighbouring areas, as a consequence of the existence of different forms of inter-regional contacts. Flows of interregional knowledge are thus important as agents of innovation, but their influence is likely to wane with distance (Anselin et al., 1997; Adams and Jaffe, 2002; Adams, 2002), as the potential for face-to-face and other forms of interaction decay.

3. The model: putting the different strands together

The three strands of literature presented above rely on three crucial factors: internal innovative efforts, socially and territorially embedded factors, and more or less spatially-bound knowledge spillovers. Although these three factors are complementary, disciplinary and methodological barriers have frequently prevented researchers working on these fields from interacting with one another. The difficulties of operationalising some of the factors in systemic and knowledge spillover approaches, given existing statistical information, provides an additional barrier for cross-fertilisation. In this section we propose a simple model which tries to combine the key factors from these three approaches in order to study how they affect innovation and how innovation influences economic growth. The model is aimed at understanding – and, to a certain extent, discriminating among – the role of the different innovation factors proposed by different strands in order to generate economic dynamism in the regions of the EU-25 after 1995. As presented in Table 1, the model combines inputs in the innovation process (R&D expenditure) with the socio-economic local factors that make the presence of favourable regional systems of innovation more likely and controls for the wealth of European regions. These factors are considered locally, i.e. the R&D and the local conditions in the region being considered, and externally, i.e. the conditions in neighbouring regions. Finally we control for the influence of national factors, such as the presence of national systems of innovation, by the introduction of a set of national dummies.

[Insert Table 1 around here]

By developing the framework above, we obtain the following model:

$$\frac{1}{T}\ln\left(\frac{Y_{i,t}}{Y_{i,t-T}}\right) = \alpha + \beta_1 \ln(y_{i,t-T}) + \beta_2 RD_{i,t-T} + \beta_3 SocFilter_{i,t-T} + \beta_4 Spillov_{i,t-T} + \beta_5 ExtSocFilter_{i,t-T} + \beta_6 ExtGDPcap_{i,t-T} + \beta_7 D + \varepsilon \tag{1}$$

where:

$\frac{1}{T}\ln\left(\frac{Y_{i,t}}{Y_{i,t-T}}\right)$ is the usual logarithmic transformation of the ratio of regional per capita GDP in region i at the two extremes of the period of analysis ([t-T,t], where t-T is the initial period, t is the final period and T is the length of the period of analysis);

α is a constant;

$\ln(y_{i,t-T})$ is the log of the GDP per capita of region *i* at the beginning of the period of analysis (t-T);

RD_{t-T} is expenditure in R&D as a % of GDP in region *i* at time (t-T);

$SocFilter_{i,t-T}$ is a proxy for the socio-economic conditions of region *i* representing its 'social filter';

$Spillov_{i,t-T}$ is a proxy for regional spillovers (accessibility to extra-regional sources of innovation);

$ExtSocFilter_{i,t-T}$ is a measure of the 'social filter' of neighbouring regions;

$ExtGDPcap_{i,t-T}$ is a measure of the GDP per capita in neighbouring regions;

D is a set of national dummy variables;

ε is the error term.

Initial level of GDP per capita – As customary in the literature on the relationship between innovation and growth, the initial level of GDP per capita is introduced in the model in order to account for the region's initial wealth and, according to Fagerberg (1988), for the stock of existing knowledge and of its distance to the technological frontier, as well[2].

R&D expenditure – As highlighted earlier, the percentage of regional GDP devoted to R&D is the main measure of the economic input in order to generate innovation in each region used by proponents of the linear model of innovation. Local R&D expenditure is also frequently used as a proxy for the local capability to adapt to innovation produced elsewhere (Cohen and Levinthal, 1990; Maurseth and

Verspagen, 1999). There are, however, measurement problems associated to this variable that must be borne in mind, as they may partially hide the contribution of R&D towards economic performance. First, the relevant time lag structure for the effect of R&D activities on productivity and growth is unknown and may vary significantly across sectors (Griliches, 1979). Second, as pointed out by Bilbao-Osorio and Rodríguez-Pose (2004) for the case of European regions, the returns from public and private R&D investments may vary significantly. Furthermore, the fact that not all innovative activities pursued at the firm level are classified as formal 'Research and Development' may be a source of further bias in the estimations. Having acknowledged these points, we assume R&D expenditure is a proxy for "the allocation of resources to research and other information-generating activities in response to perceived profit opportunities" (Grossman and Helpman, 1991, p.6) in order to capture the existence of a system of incentives (in the public and the private sector) towards intentional innovative activities.

Social Filter – The multifaceted concept of 'social filter' is introduced in the analysis by means of a composite index, which combines a set of variables describing the socio-economic realm of the region. In particular, the variables which seem to be more relevant for shaping the social filter of a region are those related to three main domains: educational achievements (Lundvall, 1992; Malecki, 1997), productive employment of human resources, and demographic structure (Fagerberg et al., 1997; Rodríguez-Pose, 1999). For the first domain, the educational attainment (measured by the percentage of the population and of the labour force having completed higher education) and participation in lifelong learning programmes are used as an indication of the accumulation of skills at the local level. For the second area, the percentage of labour force employed in agriculture and long-term unemployment are included in the analysis. The reasons for choosing these two variables are related to the traditionally low productivity of agricultural employment in relationship to that of other sectors and to the use of agricultural employment, in particular in the new members of the EU, as virtually synonymous to ‘hidden unemployment’. The role of long term unemployment as an indicator of both the rigidity of the labour market and of the presence of individuals whose possibilities of being involved in productive work are persistently hampered by inadequate skills (Gordon, 2001) is the reason behind the inclusion of this variable. The percentage of population aged between 15 and 24 was used as our measure of the demographic structure. It represents a proxy for the flow of new human resources entering the labour force and thus of the renewal of the existing stock of knowledge and skills. The European Commission has made explicit the challenges of an ageing population when regions have to rely on the benefits of a knowledge based society and highlighted “the risk of a slower spread of new technologies that could be associated with ageing” (European Commission, 2006; p.6).

From this perspective the percentage of young people is a particularly relevant indicator of the economic potential of a region, as far as its social filter is concerned.

Problems of multicollinearity prevent the simultaneous inclusion of all these variables in our model. Principal Component Analysis is therefore applied to the set of variables discussed above, in order to merge them into an individual indicator able to preserve as much as possible of the variability of the initial information. The output of the Principal Component Analysis is shown in Table 2a.

[Insert Tables 2A and 2B around here]

The eigenanalysis of the correlation matrix shows that the first principal component alone accounts for around 43% of the total variance with an eigenvalue significantly larger than 1.

Consequently, the first principal component's scores are computed from the standardised[3] value of the original variables by using the coefficients listed under PC1 in Table 2b. These coefficients emphasize the educational dimension of the social filter by assigning a large weight to the educational achievements of the population (0.576) and of the labour force (0.554) and to the participation in life long learning programmes (0.395). A negative weight is, as expected, assigned to the agricultural labour force (-0.430) and, with a smaller coefficient, to long term unemployment (-0.140). The weight of the population between 15 and 24 is much smaller (0.019) in this first principal component. This procedure provides us with a 'joint measure' for each region's social filter.

Spillovers – While in models based on knowledge production functions, spillovers are assessed in terms of their contribution towards the creation of new local knowledge, in our framework we analyse the capacity of spillovers to influence regional economic performance. For this purpose we rely on a somewhat artificial[4] distinction between intra-regional spillovers (i.e. those generated within the boundaries of the geographical unit of analysis) and extra-regional spillovers (i.e. those accruing from neighbouring regions). The aggregate nature of the data prevents us from distinguishing – within the boundaries of the individual region – between the impact of different sources of knowledge, that is to discriminate between the economic impact of the effort produced by individual innovative actors from that of the externalities produced by this process. Consequently, regional R&D investment not only proxies local innovative effort but also accounts for the impact of intra-regional spillovers. Conversely, extra-regional spillovers are proxied by a specific variable i.e. the distance-weighted innovative activities pursued in neighbouring regions. Thus, while the effect of intra-regional spillovers is captured by the R&D investment variable, where innovative activities pursued in the neighbouring regions are shown to exert a positive impact on local economic performance, there is also evidence in favour of inter-regional spillover effects: knowledge produced in one region spills over into another (through the mechanisms discussed in the previous section), influencing its economic performance. Such spillover variable captures the 'aggregate' impact of innovative activities pursued in the neighbourhood (and its sensitivity to geographical distance), but does not allow us to single out whether and to what extent this process is the result of intentional (either market-mediated or non-market mediated contacts) knowledge flows or of unintentional spillovers[5]. The significance of this indicator suggests that accessibility to extra-regional innovation permits the inter-regional transfer of knowledge. In particular, in the framework presented in the previous section, face-to-face contacts enable the transmission of non-codifiable knowledge which, in turn, has an impact on regional growth. Furthermore, the transmission of formally codified knowledge, which is less sensitive to proximity relationships for its diffusion, is also partially captured by this 'spatial' variable. Even if the differential impact of formally codified knowledge flows depends more on the local absorptive capacity (Cohen and Levinthal, 1990) than on geographical constraints, research on patent citations suggests that proximity facilitates a faster diffusion of the latter kind of knowledge as well (Sonn and Storper, 2005).

For this purpose we develop a measure of 'accessibility' to extra-regional innovative activities, introduced in the analysis by means of a standardised 'index of accessibility to innovation'[6]. The index is a potential measure of the 'innovative activities' (in terms of nationally weighted millions of Euros invested in R&D activities) that can be 'reached' from each region at a 'cost' which increases with distance.

Our index is based on the usual formula for accessibility indices:

$$A_i = \sum_j g(r_j) f(c_{ij}) \qquad (2)$$

Where A_i is the accessibility of region i, r_j is the activity R to be reached in region j, c_{ij} is the generalised cost of reaching region j from region i and g(·) and f(·) are the 'activity' function (i.e. the activities/resources to be reached) and the 'impedance' function (i.e the effort, cost/opportunity to reach the specific activity) respectively. In our index the 'activity' to be reached is R&D expenditure, thus:

$g(r_j) =$ (R&D expenditure)$_j$

and the 'impedance' is the bilateral trip-time distance between region *i* and region *j*:

$$f(c_{ij}) = \begin{cases} w_{ii} = 0 & \text{if } i=j \\ w_{ij} = \dfrac{\frac{1}{d_{ij}}}{\sum_j \frac{1}{d_{ij}}} & \text{if } i\neq j \end{cases} \qquad (3)$$

where d_{ij} is the average trip-length (in minutes) between region *i* and *j* and *w* the corresponding inverse-distance weight.

We base our analysis on the travel time calculated by the IRPUD (2000) for the computation of peripherality indicators and made available by the European Commission[7]. We chose road distance, rather than straight line distance, as it gives a more realistic representation of the real 'cost' of interaction and contacts across space.

In addition the use of trip-length rather than kilometres allows us to take account of "different road types, national speed limits, speed constraints in urban and mountainous areas, sea journeys, border delays (…) as also congestion in urban areas" (IRPUD, 2000, p.22), which significantly affect real-world interactions.

The amount of knowledge flowing from outside the region is thus proxied by the average magnitude of all other regions' R&D expenditure weighted by the inverse of the bilateral time-distance. The resulting variable is then standardised by making it range from zero to one, in order to make it perfectly comparable with the social filter index.

Extra regional social filter – Following a similar procedure we calculate, for each region, the inverse-distance-weighed average of the social filter index of all the other regions in the EU. As a consequence $f(c_{ij})$ remains the same as in equation (2), while:

$g(r_j)$ becomes the *Social Filter Index*$_j$

The aim of including this variable is to assess whether proximity to regions with favourable social conditions and dynamic innovation systems matters, i.e. whether socio-economic and institutional spillovers have a similar role to knowledge spillovers. Given that "innovation systems can be viewed as institutional arrangements to facilitate spillovers (provide connectivity) among economic actors" (Carlsson, 2004, p.4), when such connectivity is assessed in its inter-regional scope, being in an innovation-prone neighbourhood may enhance the local capability to absorb and produce innovation.

GDP in neighbouring regions – Again the same weighing procedure is pursued in order to introduce the initial economic conditions (GDP per capita) of neighbouring regions. In this case:

$g(r_j)$ denotes *GDP per capita*$_j$ in equation (2)

This variable accounts for the advantage of proximity to relatively well-off regions.

Although the introduction of these two final variables is suggested by the detection of spatial autocorrelation in the residuals of previous specifications (reflecting the spatial structure of the data), their justification stems directly from the model underlying this paper. As presented in Table 1, the model explicitly aims at assessing the impact of both internal and external conditions on regional innovative performance. Consequently, the inclusion of the social-filter and economic wealth in neighbouring regions makes it possible to isolate the impact of a favourable geographical location of any given region not only in terms of its capacity to reap knowledge spillovers, but also to benefit from other innovation-enhancing conditions of interconnected regions.

4. Results of the analysis

4.1 Estimation issues and data availability

In this section we estimate the model outlined above by means of heteroskedasticity-consistent OLS (Ordinary Least Square). In order to minimize the effect of spatial autocorrelation (i.e the lack of independence among the error terms of neighbouring observations), we include in the analysis a set of national dummy variables, accounting for 'national fixed effects', which, in turn, take into consideration a consistent part of the similarities between neighbouring regions. Furthermore, by introducing spatially lagged variables in our analysis, we explicitly aim at modelling the interactions between neighbouring regions and thus minimizing their effect on the residuals. Another major problem concerns endogeneity, which we address by including in the model the value of the explanatory variables as a mean over the five years preceding the first year of the period of analysis (i.e. over the period [t-T-5, t-T]), while the average growth rate was calculated over the period [t-T, t][8]. In addition, in order to resolve the problem of different accounting units, explanatory variables are expressed, for each region, as a percentage of the respective GDP or population.

The empirical model was estimated for the period 1995-2003, allowing us to include all the EU-25 members for which regional data are available. Because of data constraints, but also for reasons of homogeneity and coherence in terms of the relevant institutional level, the analysis uses NUTS1 regions for Germany, Belgium, and the UK and NUTS2 for all other countries (Spain, France, Italy, the Netherlands, Greece, Austria, Portugal, Finland, Czech Republic, Hungary, Poland, and Slovakia). Countries without a relevant regional articulation (Denmark, Ireland, Luxemburg, Estonia, Latvia, Lithuania, Slovenia, Malta, and Cyprus) were necessarily excluded from the analysis[9]. In addition, regional data on R&D expenditure are not available in the Eurostat databank for Sweden. In total, 166 regions from 15 different countries are covered in the analysis.

EUROSTAT Regio data, the main source of information, have been complemented with Cambridge Econometrics (CAMECON) data for GDP. Table A-1 in the appendix provides a detailed definition of the variables included in the analysis.

4.2 Innovation, spillovers and social filter

The estimation results for the empirical model outlined in the previous section are presented in Table 3. The results of different regressions are reported. In Regressions 1-3 the variables for 'social filter' and 'accessibility to external sources of innovation' are progressively introduced. In Regressions 4-9 the individual components of the social filter are introduced separately in order to discriminate among them. In Regressions 10-12 the effect of the endowment of neighbouring regions in terms of social filter and economic wealth is assessed.

The R^2 confirms the overall goodness-of-fit of all the regressions presented and, in all cases, the probability of the F-statistics lets us reject the null hypothesis that all of the regression coefficients are zero. V.I.F. tests have been conducted for the variables included in all the specifications of the model excluding the presence of multicollinearity. No spatial autocorrelation in the residuals was detected using Moran's I statistic[10].

[Insert Table 3 around here]

Several implications can be extracted from the results of the empirical analysis. First is that the initial level of GDP per capita is significant in a few cases only, thus suggesting that for the period under analysis, neither regional convergence, nor divergence can be recorded (Rodríguez-Pose and Fratesi, 2004). Only when social conditions are explicitly controlled for (regressions 3, 10, 11 and 12) there is evidence of a weak degree of regional convergence. However, the magnitude of the convergence parameter, where significantly different from zero, is in all cases very small, implying a speed of convergence of 0.6% per year, with a half-life of approximately 102 years.

Second, local R&D expenditure generally shows a positive and significant relationship with economic growth in all regressions, in line with earlier research (Fagerberg et al., 1997; Rodríguez-Pose, 1999, 2001; Cheshire and Magrini, 2000; Bilbao-Osorio and Rodríguez-Pose, 2004; Crescenzi, 2005). For the European regions considered, investing in R&D seems to be a more important source of economic growth than relying of knowledge spillovers from neighbouring regions. When considering both factors together (Regression 1) the coefficient of local R&D expenditure is positive and significant, while the impact of innovation generated outside the region is insignificant. Relying exclusively on local R&D inputs is, however, not a guarantee for achieving greater growth, as such relationship proves to be not always robust when controlling for social conditions (the 'social filter' variable). As highlighted in Regression 2, the local socio-economic conditions are a better predictor of economic growth than investment in R&D. The social filter variable is always positively associated with economic growth and statistically significant. The relevance of the 'social filter' is enhanced when R&D investment and exposure to knowledge spillovers are considered in conjunction with local conditions (Regression 3). The results point out that having a good social filter increases the potential of European regions to assimilate spillovers, making local R&D expenditure irrelevant. These results highlight that while investing in R&D locally enhances economic growth, relying of knowledge spillovers stemming from other regions is an important alternative source of competitive advantage where adequate socio-economic structures – that would guarantee the reception and assimilation of those spillovers – exist. This does not mean that local innovative efforts are unimportant for regional economic performance. However, as far as knowledge may flow also from outside the region (both in the form of codified and non-codified knowledge spillovers), local socio-economic conditions may prove to be the true differential competitive factor by enabling the translation of all sources of knowledge into successful innovation and economic growth.

Introducing the individual sub-components of the social filter uncovers the specific importance of the educational endowment of both the population and the labour force for economic growth (Regressions 4 and 5). The role of life-long learning, the percentage of the labour force working in agriculture, the level of long term unemployment, and the demographic structure of the population, are, in contrast, not significant. Agricultural employment and long-term unemployment, in addition, limit the capacity of regions to assimilate knowledge spillovers (Regressions 6 and 7). In these cases, relying on knowledge spillovers is no substitute of local investment in R&D.

The results underscore that accessibility to extra-regional innovation, our proxy for knowledge spillovers, is related in a positive and statistically significant way to regional growth performance, in particular when associated to an appropriate measure for socio-economic conditions. This confirms that knowledge spillovers, by increasing the 'amount of knowledge' available in the region, reinforce the effect of local innovative activities, and, to a certain extent, may even compensate for a weak contribution of the innovative activities pursued locally. Thus, other things being equal, a region within an innovative neighbourhood is more advantaged than one in the vicinity of less innovative areas. In contrast, both the socio-economic endowment (Regression 11) and the level of wealth (Regression 12) of neighbouring regions (i.e. extra-regional wealth) have no significant effect on local economic performance. The extra-regional social filter is significant only when considered jointly with internal features, as in Regression 10 where the total accessibility to innovation prone space is considered by including in a single variable both the region's features and that of its neighbourhood[11].

On the basis of these results, the economic potential of a region is maximized when an appropriate set of social conditions is combined with local investment in R&D. The reception of R&D spillovers from neighbouring regions is an important additional source of advantage which, in any case, requires an appropriate social infrastructure in order to be productively translated into innovation and economic growth. In this framework the analysis of the spatial scope of such spillovers, which we will discuss in the next subsection, becomes particularly important for understanding the role of geography in a knowledge-based economy.

4.3 The spatial extent of innovative spillovers

Understanding the spatial scope of knowledge spillovers is extremely relevant from both a theoretical and a public policy point of view. Even if, as discussed in section 2, a variety of contributions provides significant evidence in support of the role of proximity as a relevant factor for the transmission of knowledge, in a recent review of the research on geographical knowledge spillovers, Döring and Schnellenbach (2006) highlight that "no consensus is reached about the spatial range that can be attributed to knowledge spillovers, and in fact the majority of studies refuse to quantify the range at all" (p.384). Since the seminal work by Anselin et al. (1997) on the influence of the location of universities and private R&D facilities on local innovative productivity, the spatial extent of knowledge flows in the US has been extensively studied. Acs (2002, ch.3) compares the results of a number of earlier studies based on different estimation techniques and concludes that university research spills over a range of 50 miles from the innovative Metropolitan Statistical Areas (MSAs), while the spillovers from private R&D tend to be contained within the MSA itself. Even if such results adjust downward the 75 mile radius previously measured by Varga (2000), the range 50-75 miles provides a 'consolidated' measure for the geographical extent of knowledge spillovers in the US case. At the EU level, the scarcity (and heterogeneity) of research efforts in this direction have prevented the formation of any consensus. Greunz (2003) finds a positive and significant effect on local patenting activity of innovative efforts pursued in first and second order neighbouring regions (190 miles or 306 Km on average). The magnitude of this effect sharply decreases when reaching the third order neighbourhood (274 miles or 441 Km on average) and is no longer significant thereafter. Bottazzi and Peri (2003) find evidence of spillover effects, with a positive impact of neighbouring regions' R&D efforts on local productivity, only within a 200-300 km limit. In the same vein, Moreno et al. (2005) estimate a similar spatial scope of regional spillovers: "innovative activity in a region is positively related to the level of innovative activity in regions located within 250 kilometres of distance, but no further" (p.7). Our analysis helps filling the existing gap in the empirical literature on the measure of the spatial extent of regional spillovers in the EU by including the regions of the entire EU25. In addition, our empirical analysis, while delivering comparable results, differs from previous studies in that:

a) it is not based on a Knowledge Production Function but on a regional growth model thus capturing the effects of neighbouring regions' innovative efforts on the overall productivity of the regional economy, rather than on the production of innovative output only;

b) distance is introduced into the model by means of a (time-based) trip-length measure which captures more accurately the differential quality of connections between regions;

c) the model explicitly accounts for the underlying socio-economic conditions.

In what follows, we focus in greater detail on the relevant ‘spatial scale’ for the transmission of growth-enhancing knowledge spillovers, by attempting to quantify the concept of ‘proximity’ for the regions of the EU-25.

[Insert Table 4 around here]

Table 4 presents various estimations of our empirical model in which regional spillovers’ proxies are calculated by means of different ‘spatial weights’. As in the case of the regressions presented in Table 3 all usual diagnostic statistics confirm the robustness of our results.

Regression 1, used as the benchmark, shows our estimation results when regional spillovers are proxied by the index of accessibility to extra-regional innovation as in all regressions in the previous table. The regression not only confirms that knowledge flowing from neighbouring regions improves regional growth performance, as was underlined before, but also shows that spillovers are geographically bounded and decay with distance. The weighing mechanism on which the variable is based makes the importance of other regions’ innovative activities decrease with distance thus emphasizing the effect of innovative activities pursued in neighbouring regions. More precisely, regions can rely upon the research strength of regions within a three hour drive (ca 200 kms) as shown by the increase in significance of the spillover variable once a 180 minute cut off is introduced in the weighing matrix (Regression 2). When more remote regions are taken into consideration, by fixing the cut off trip length at 300 and 600 minutes (Regressions 3 and 4 respectively), the variable is no longer significant thus showing that beyond a 180 minute trip-time the returns to extra-regional innovative activities are inexistent. Such measure for the spatial extent of regional spillovers is, as discussed above, in line with the empirical evidence produced so far. However, trip-length distance has allowed a more accurate measure of distance as a barrier to human interactions across geographical space. These results are confirmed also when total accessibility to innovative activities is considered by introducing a variable capturing both internal and distance-weighed R&D expenditure (Regressions 5-12). In this second case the 'institutional' borders of the region are overcome by focusing on a 'continuous' space which results from the aggregation, in an individual variable, of the total R&D expenditure that can be reached from a certain location regardless of regional borders. In doing this, we aim to measure the total impact of R&D agglomeration on economic performance.

Our results show once again that only the variables combining the strength of internal efforts with those pursued in more proximate (within the 180 minutes limit) areas produce a positive and significant effect on regional growth performance. The 180 minutes limit for interregional knowledge flows comes to reinforce the idea of a 'human-embodied' transmission technology since it allows the maximization of face-to-face contacts between agents. Agents within driving distance from one another can exchange their information face-to-face potentially on a daily basis, at a much lower marginal cost in comparison to those where an overnight stay is necessary (Sonn and Storper, 2005).

5. Conclusions

The objective of this paper has been to analyse, for EU regions, the role played by the different combinations of factors identified by different approaches to the study of innovation, and to discriminate among them. The results of the empirical analysis uncover the importance not only of the traditional linear model local R&D innovative efforts, but also of the local socio-economic conditions for the genesis and assimilation of innovation and its transformation into economic growth across European regions. In addition, it shows the importance of proximity for the transmission of economically productive knowledge. The results highlight that not only knowledge flowing from neighbouring regions improves regional growth performance, but also that spillovers are geographically bounded and that there is a strong distance decay effect, which in the European case expands to more or less a 200 km radius. These outcomes shed additional light on the role of geography in the process of innovation, by supporting the idea of an existing tension between two forces: the increasingly homogeneous availability of standard 'codified' knowledge and the spatial boundedness of 'tacit' knowledge and contextual factors. Such tension is an important force behind the present economic geography of European regions and its role is further accentuated by the underlying socio-economic differences.

The analysis also has important regional policy implications. When innovation is recognized as the key source of sustained economic growth, the mechanics of its contribution to economic performance becomes crucial for an effective policy targeting. In this respect the results of the analysis show that, in terms of innovation, a region can rely on both internal and external sources of innovation, but that the socio-economic conditions in order to maximize the innovation potential of each region are necessarily internal, as socio-economic conditions in neighbouring regions do not have any substantial impact on local economic performance.

Consequently, policies based on innovation may deliver, at a regional level in Europe, very different results, according to the possibility of every region of benefiting from knowledge spillovers (location advantage) and favourable underlying socioeconomic conditions (internal conditions). R&D investment in core regions, which benefits from both a location and social filter advantage, is overall more conducive to economic growth due to its impact on both local and neighbouring regions' performance. Conversely, in peripheral regions investment in R&D may not yield the expected returns. The limited R&D investment capacity of regions in the periphery, their inadequate social filters, and their lower exposure, because of their location, to R&D spillovers are likely to undermine the R&D effort conducted within the borders of these regions. Does this mean that it is not worth investing in innovation in the periphery? While investing in promoting innovation is likely to remain a key factor for the development of peripheral regions in Europe, these sort of policies will need, much more than in the case of core regions, to be complemented by policies specifically aimed at tackling the local social and economic barriers that prevent the generation and the reception and assimilation of innovation. This fundamentally implies developing policies targeted at improving education, training, and skills, in order to guarantee not only greater returns from any innovation effort, but also – and perhaps more importantly in these environments – a better assimilation of knowledge spillovers generated in neighbouring regions and a better transformation of innovation into economically productive activities.

Overall, our analysis supports the idea that while the neo-Schumpeterian threshold of expenditure is an important factor in determining the returns of investment in R&D, for most regions in the EU addressing the capacity of the local population to assimilate whatever research is being generated locally or in neighbouring regions and to transform it into innovation and economic activity may be an important condition for the success of innovation-based economic development policies. However, the road ahead for peripheral regions in Europe is likely to remain tortuous. Given the structural constraints that many backward regions face, the potential transformation of the European periphery into innovation prone societies – if it ever happens – will in most cases be a slow process, fraught with difficulties.

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Endnotes

1. In this paper we adopt the definition of 'knowledge' developed by Döring and Schnellenbach (2006): we understand "knowledge as comprising all cognitions and abilities that individuals use to solve problems, make decisions and understand incoming information (…), knowledge is a tool that can be consciously used by individuals" (p.377).
2. GDP per capita is usually considered as a proxy for the level of productivity: the lower the productivity (GDP per capita) of a region, the farther it is from its technological frontier.
3. Standardised in order to range from zero to 1
4. As discussed in the previous section there is no reason that knowledge should stop spilling over just because of the (often arbitrary) boundaries of the NUTS regions on which the analysis is based.
5. Taking into account these caveats, our measurement of spillovers represents not only 'pure knowledge externalities' but also, more generally, the broader set of knowledge flows produced by any external source and appropriated by local innovative agents. "The pathways by which knowledge spills over in this way are many and various; they include written texts, informal conversations, input-output links, inter-firm mobility of workers, strategic alliances and so on" (Scott, 2006, p.9). The analysis of such pathways is outside the scope of this paper which, in this regard, inevitably shares the limitations of other studies based on a similar approach (compare Breschi and Lissoni, 2001).
6. The indicator of accessibility to innovation used in this article is purely geographical. While we acknowledge that geographical distance may neither be a sufficient, nor a necessary condition for the assimilation of spillovers, and cognitive, organizational, social, and institutional proximity play an important role

in the diffusion of knowledge (Boschma, 2005; see also Iammarino and McCann, 2006), the quantitative nature of the analysis prevents us from focusing on these other forms of proximity. Hence we measure the geographical distance between different socio-economic structures in regions, but not the social distance between these same structures.

7. As the time distance-matrix is calculated either at the NUTS1 or at the NUTS2 level, in order to make it coherent with our data which combine different Nuts levels we relied on the NUTS distance matrix using the NUTS 2 regions with the highest population density, in order to represent the corresponding NUTS1 level for Belgium, Germany, and the UK.
8. In the case of the New Member States data availability has prevented us from calculating the mean of the explanatory variables over the five year period (t-T-5) forcing us to use a shorter time span. For some EU 15 countries slightly different time spans have been used, as a consequence of differences in data availability for each variable.
9. As far as specific regions are concerned, no data are available for the French Départments d'Outre-Mer (Fr9), Uusimaa (Fi16) and Etela-Suomi (Fi17) were excluded from the analysis due to the lack of data on socio-economic variables. Trentino-Alto Adige (IT31) was also excluded as it has no correspondent in the NUTS2003 classification. Due to the nature of the analysis, the islands (PT2 Açores, PT3 Madeira, FR9 Departments d'Outre-Mer, ES7 Canarias) and Ceuta y Melilla (ES 63) were not considered, as time-distance information, necessary for the computation of spatially lagged variables, is not available.
10. The value of the Moran's I from the regression residuals is reported in the tables for each regression, alongside the usual diagnostic statistics. The weight matrix for the computation of the Moran's I is based on the same weighting scheme

(Equations 2 and 3) adopted for the calculation of the spatially lagged variables included in the model (spillovers and social filter conditions of neighbouring regions). In addition to this weighting scheme (based on distance), first order contiguity has been also tested delivering similar results.

11. In this case:

$$f(c_{ij}) = \begin{cases} w_{ii} = 1 & for i = j \\ w_{ij} = \dfrac{\frac{1}{d_{ij}}}{\sum_j \frac{1}{d_{ij}}} & for i \neq j \end{cases} \quad (4)$$

As a result the variable is equal to the sum of the region's social filter index and the inverse-distance weighted average of other regions' social filter index (Accessibility to Innovation Prone Extra-Regional areas).

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Table 1 – Structure of the empirical model

	Internal factors	External factors (Spillovers)
R&D	Investment in R&D in the region	Investment in R&D in neighbouring regions
Regional systems of innovation	Conditions conducive to the establishment of a regional system of innovation	Conditions conducive to the establishment of a regional system of innovation in neighbouring regions
GDP per capita	As a proxy for initial conditions and potential	Initial conditions in neighbouring regions
National effect	Controlled for by a set of national dummies	

Table 2a - Principal Component Analysis: Eigenanalysis of the Correlation Matrix

	PC1	*PC2*	*PC3*	*PC4*	*PC5*	*PC6*
Eigenvalue	2.5886	1.2723	0.9083	0.6418	0.5661	0.0229
Proportion	0.431	0.212	0.151	0.107	0.094	0.004
Cumulative	0.431	0.643	0.795	0.902	0.996	1

Table 2b - Principal Component Analysis: Principal Components' Coefficients

Variable	*PC1*	*PC2*
Education Population	0.576	-0.224
Education Labour Force	0.554	-0.313
Life-Long Learning	0.395	0.26
Agricultural Labour Force	-0.43	-0.285
Long Term Unemployment	-0.14	-0.459
Young People	0.019	0.701

Table 3 - H-C OLS estimation of the empirical model. R&D, social filter and knowledge spillovers. Annual growth rate of regional GDP (1995-2003).

	1	2	3	4	5	6	7	8	9	10	11	12
Constant	0.09406***	0.12284***	0.12182***	0.1126***	0.10707***	0.09655***	0.08491***	0.08989***	0.10777***	0.12054***	0.12187***	0.12059***
	(0.02572)	*(0.02814)*	*(0.02796)*	*(0.02563)*	*(0.02561)*	*(0.02671)*	*(0.03019)*	*(0.0292)*	*(0.02709)*	*(0.02802)*	*(0.02805)*	*(0.02809)*
Log GDP 95	-0.003098	-0.005756	-0.00663*	-0.00574*	-0.005112	-0.003359	-0.00196	-0.002733	-0.004345	-0.006577*	-0.006349*	-0.007705*
	(0.003255)	*(0.00353)*	*(0.003543)*	*(0.003267)*	*(0.003268)*	*(0.003346)*	*(0.003803)*	*(0.003478)*	*(0.003339)*	*(0.003571)*	*(0.003668)*	*(0.003929)*
R&D expenditure	0.2682**	0.1424	0.1791	0.1366	0.166	0.2556**	0.2664**	0.2653**	0.2548**	0.1883	0.177	0.1909
	(0.1174)	*(0.1207)*	*(0.1218)*	*(0.1212)*	*(0.1208)*	*(0.1229)*	*(0.1177)*	*(0.1182)*	*(0.1172)*	*(0.1213)*	*(0.1223)*	*(0.1234)*
Social Filter Index		0.01052**	0.010787**								0.010538**	0.011422**
		(0.004626)	*(0.004598)*								*(0.004682)*	*(0.004713)*
Accessibility to ExtraRegional Innovation	0.013236		0.01387*	0.013157*	0.013733*	0.012717*	0.012262	0.013353	0.013807*	0.014184*	0.013936*	0.014229*
	(0.008148)		*(0.008031)*	*(0.007908)*	*(0.007975)*	*(0.0083)*	*(0.008336)*	*(0.008182)*	*(0.008119)*	*(0.008052)*	*(0.008059)*	*(0.008067)*
National Dummies	x	x	x	x	x	x	x	x	x	x	x	x
Social Filter Individual Components:												
Education Population				0.017003***								
				(0.005341)								
Education Labour Force					0.019224***							
					(0.006986)							
Life-Long Learning						0.00385						
						(0.01076)						
Agricultural Labour Force							0.003802					
							(0.006528)					
Long Term Unemployment								0.001892				
								(0.006205)				
Young People									-0.009089			
									(0.005882)			
Extra-Regional Social Filter												
Total accessibility to innovation prone space										0.012617***		
										(0.005656)		
Accessibility to Innovation Prone Extra-Regional areas											-0.00808	
											(0.0261)	
Accessibility to wealth neighbouring regions												8.8E-07
												(0.00000138)
Observations	166	166	166	166	166	166	166	166	166	166	166	166
R-Sq	0.659	0.665	0.672	0.681	0.676	0.66	0.66	0.659	0.665	0.67	0.672	0.672
R-Sq (adj)	0.62	0.626	0.631	0.642	0.636	0.618	0.618	0.618	0.624	0.63	0.629	0.63
F	16.84	17.27	16.7	17.45	17.03	15.82	15.85	15.81	16.19	16.61	15.72	15.77
Moran's I	-0.0193012	-0.0185667	-0.0189041	-0.0194612	-0.0198153	-0.0193265	-0.0198503	-0.0195195	-0.0199182	-0.0188243	-0.0188376	-0.0189403

*, ** and *** denote significance at a 10%,5% and 1% level respectively. SE in parentheses

Table 4 - H-C OLS estimation of the empirical model: accessibility to innovation. Annual growth rate of regional GDP (1995-2003).

	1	2	3	4	5	6	7	8	9	10	11	12
Constant	0.12182***	0.134***	0.12317***	0.12551***	0.12107***	0.12176***	0.1216***	0.12116***	0.09082***	0.09202***	0.08063***	0.09103***
	(0.02796)	*(0.02838)*	*(0.02822)*	*(0.02844)*	*(0.028)*	*(0.02799)*	*(0.02799)*	*(0.028)*	*(0.02532)*	*(0.02533)*	*(0.02512)*	*(0.02533)*
Log GDP 95	-0.00663	-0.007635**	-0.006016*	-0.005813	-0.005554	-0.005661	-0.005642	-0.005572	-0.001745	-0.001913	-0.000093	-0.001779
	(0.003543)	*(0.003612)*	*(0.003571)*	*(0.003537)*	*(0.003506)*	*(0.003506)*	*(0.003505)*	*(0.003506)*	*(0.003166)*	*(0.003168)*	*(0.003078)*	*(0.003168)*
R&D expenditure	0.1791	0.1486	0.1458	0.1475								
	(0.1218)	*(0.1194)*	*(0.1211)*	*(0.1211)*								
Social Filter Index	0.010787**	0.01074**	0.01101**	0.010379**	0.01081**	0.010656**	0.010685**	0.010782**				
	(0.004598)	*(0.004579)*	*(0.004724)*	*(0.004638)*	*(0.00455)*	*(0.004538)*	*(0.004538)*	*(0.00455)*				
Accessibility to ExtraRegional Innovation												
Continuous Space	0.01387*											
	(0.008031)											
180 minutes cutoff		0.00983**										
		(0.00481)										
300 minutes cutoff			0.002556									
			(0.004712)									
600 minutes cutoff				-0.005154								
				(0.007263)								
Total accessibility to Innovation (Extra+Intra regional)												
Continuous Space					0.005349				0.008264*			
					(0.004505)				*(0.004401)*			
180 minutes cutoff						0.006191				0.009091**		
						(0.004619)				*(0.004518)*		
300 minutes cutoff							0.006103				-0.000643	
							(0.004628)				*(0.004707)*	
600 minutes cutoff								0.005447				0.00836*
								(0.004506)				*(0.004402)*
National Dummies	x	x	x	x	x	x	x	x	x	x	x	x
Observations	166	166	166	166	166	166	166	166	166	166	166	166
R-Sq	0.672	0.674	0.666	0.666	0.665	0.666	0.666	0.665	0.652	0.653	0.644	0.652
R-Sq (adj)	0.631	0.634	0.625	0.625	0.626	0.627	0.627	0.627	0.615	0.616	0.606	0.615
F	16.7	16.89	16.25	16.28	17.27	17.34	17.33	17.28	17.46	17.55	16.84	17.47
Moran's I	-0.0189041	-0.0196286	-0.0186123	-0.019055	-0.0189909	-0.0192397	-0.0191901	-0.0189931	-0.0188665	-0.0191502	-0.0165446	-0.0188604

*, ** and *** denote significance at a 10%,5% and 1% level respectively. SE in parentheses

Appendix

Table A-1 – Description of the variables

Variable	**Definition**
Dependent variable	Annual growth rate of regional GDP (1995-2003)
Internal factors	
Log GDP 95	Natural logarithm of regional GDP per capita
Innovation	
R&D	Expenditure on R&D (all sectors) as a % of GDP
Social Filter	
Life-Long Learning	Rate of involvement in Life-long learning - % of Adults (25-64 years) involved in education and training
Education Labour Force	% of employed persons with tertiary education (levels 5-6 ISCED 1997).
Education Population	% of total population with tertiary education (levels 5-6 ISCED 1997).
Agricultural Labour Force	Agricultural employment as % of total employment
Long Term Unemployment	Long term unemployed as % of total unemployment.
Young People	People aged 15-24 as % of total population
Social Filter Index	The index combines, by means of Principal Component Analysis, the variables describing the socio-economic realm of the region (listed above).
External factors (Spillovers)	
Accessibility to ExtraRegional Innovation	Index A_i which, for each region i, is the inverse-distance-weighted average of nationally-weighted millions of Euros invested in R&D activities of the n_j-1 (with $j \neq i$) regions.
Total accessibility to Innovation	For each region i, is the inverse-distance-weighted average of the nationally-weighted millions of Euros invested in R&D activities over N regions (including region i it self, with weight w_{ii} =1)
Accessibility to Innovation Prone Extra-Regional areas	For each region i, is the inverse-distance-weighted average of the Social Filter Index over the n_j-1 (with $j \neq i$) regions.
Total accessibility to innovation prone space	For each region i, is the inverse-distance-weighted average of the Social Filter Index over N regions (including region i it self, with weight w_{ii} =1)
Accessibility to wealth neighbouring regions	For each region i, is the inverse-distance-weighted average of the GDP per capita over the n_j-1 (with $j \neq i$) regions.